NEW CROSS SECTION MEASUREMENTS AND THEIR APPLICTIONS TO COSMIC RAY PROPOGATION QUESTIONS USING DATA FROM HEAO-3-C2 EXPERIMENT

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FINAL REPORT
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In 1982 we embarked on a program to measure cross sections in hydrogen and helium targets that would be applicable to the problem of cosmic ray progagation through the material in our galaxy. This required the measurement of several hundred cross sections at energies from ~0.3 to 1.7 GeV/nuC at the BEVALAC to an accuracy ~5%. This program consisted of one or two trips to the BEVALAC each year to make these measurements with a newly designed charge-isotope telescope that we built. A list of these runs and the beams of particles used is given in Table I. Additional runs, supported by other grants have been made after the expiration of grant NAG8-606.

The reduction of this data has been a massive task that was completed in early 1989. This has resulted in the most complete set of cross sections for hydrogen and helium targets that is presently available to the cosmic ray as well as the nuclear physics community. This work has been reported in a number of conference publications during the 1982-1988 time period. For the purposes of this final report we list only the 5 major publications that have summarized this work. A copy of the 1988 publication of the helium cross sections is enclosed. This work is still continuing today and has been the subject of dozens of papers by various groups applying these cross sections.

BEVALAC FRAGMENTATION RUNS

DATE	CHARGES	BEAM ENERGY (MeV/nuc)	CH_2 TARGET THICKNESS* (g/cm^2)	Z-ANALYSIS Z =	A-ANALYSIS Z =	REMARKS
1980-April	^{56}Fe	710	3.51	10-26	16-26	(1)
	^{56}Fe	1010	5.51	10-26	18-26	(1)
1982-Oct	^{16}O	500	9.02	4-8	5-8	(2)
	^{16}O	720	9.02	4-8	---	
	^{16}O	950	9.02	4-8	---	
	^{20}Ne	540	9.02	4-10	6-10	(2)
1983-Dec	^{12}C	450	6.01	3-6	4-6	(3)
	^{28}Si	590	6.01	6-14	10-14	(3)
	^{28}Si	870	6.01	6-14	10-14	(3)
	^{28}Si	1350	6.01	5-14	-----	
	^{56}Fe	400	2.51	16-26	-----	
	^{56}Fe	580	2.75	16-26	24-26	(3)
	^{56}Fe	1180	6.01	12-26	24-26	(4)
	^{56}Fe	1700	6.01	10-26	-----	
1984-Aug	^{12}C	435	6.01	3-6	4-6	(5)
	^{12}C	730	8.76	3-6	-----	
	^{12}C	1050	8.76	3-6	-----	
	^{20}Ne	670	6.01	4-10	-----	
	^{40}Ar	590	5.26	8-18	12-18	(5)
	^{40}Ar	870	6.01	8-18	16-18	(6)
1985-April	^{24}Mg	380	6.01	5-12	-----	
	^{24}Mg	540	6.01	5-12	7-12	(7)
	^{24}Mg	790	6.01	5-12	8-12	(8)
	^{24}Mg	1500	6.01	5-12	-----	
	^{56}Fe	600	3.51	12-26	16-26	(7)
	^{56}Fe	1500	6.01	10-26	-----	
	^{58}Ni	640	2.75	14-28	26-28	(7)
1985-Nov	^{20}Ne	645	6.01	5-10	6-10	(9)
	^{20}Ne	1095	6.01	5-10	-----	
	^{32}S	720	6.01	6-16	10-16	(9)
	^{32}S	1200	6.01	6-16	-----	
	^{40}Ca	760	6.01	8-20	14-20	(9)
1986-Nov	^{12}C	610	11.13	4-6	4-6	(10,11)
	^{12}C	950	8.75	4-6	-	(10,11)
	^{12}C	1600	8.75	4-6	-	(10,11)
	^{16}O	640	8.75	4-8	5-8	(10,11)
	^{16}O	1600	8.75	4-8	-	(10,11)
	^{56}Fe	840	6.01	16-26	-	(10,11)
	^{56}Fe	850	6.01	12-26	16-26	(10,11)
	^{56}Fe	1600	6.01	10-16	-	(10,11)

* C target thickness chosen to have same E loss as CH_2

(1) Cerenkov = Pilot 425, n=1.515, Z=1, 130 p.e., Total energy = NE102

(2) Cerenkov = Fused Silica B+WLS, n = 1.505, Z=1, 170 p.e., Total energy = NE102

(3) Cerenkov = Fused Silica A+WLS, n = 1.505, Z=1, 240 p.e., Total energy = NE102

(4) Cerenkov = FC-72+WLS, n = 1.263, Z=1, 165 p.e., Total energy = SCG-1 glass

(5) Cerenkov = Fused Silica A+WLS, n = 1.505, Z=1, 240 p.e., Total energy = NaI or SCG-1

(6) Cerenkov = FC-72+WLS, n = 1.263, Z=1, 1.65 p.e., Total energy = SCG-1 glass

(7) Cerenkov = Fused Silica A+WLS, n = 1.505, Z=1. 275 p.e., Total energy = NaI

(8) Cerenkov = FC-72+WLS, n=1.263, Z=1, 1.65 p.e., Total energy = NaI

(9) Cerenkov = H_2O + WLS, n = 1.338, Z=1, 170 p.e., Total energy = NaI

(10) These runs included a 5.0 g/cm^2 liquid He target supplied by P. Goret and collaborators at SACLAY.

(11) Cerenkov = Teflon + WLS, n = 1.335, Z=1, 185 p.e., Total Energy = NaI.

Major Publications Summarizing this Cross Section Work

1. Measurement of ^{12}C, ^{16}O and ^{56}Fe charge changing cross sections in helium targets at high energy, comparison with cross sections in hydrogen, and application to cosmic ray propagation., P. Ferrando, W.R. Webber, P. Goret, J.C. Kish, D.A. Schrier, A Soutoul and O. Testard, Phys. Rev. C., 37, 1490, 1987.

2. Total Charge and mass changing cross sections of relativistic nuclei in hydrogen, helium and carbon targets, W.R. Webber, J.C. Kish, and D.A. Schrier, Phys. Rev. C., 41, 1990.

3. Individual charge changing fragmentation cross sections of relativistic nuclei in hydrogen, helium, and carbon targets, W.R. Webber, J.C. Kish and D.A. Schrier, Phys. Rev. C., 41, 1990.

4. Individual isotopic fragmentation cross sections of relativistic nuclei in hydrogen, helium and carbon targets, W.R. Webber, J.C. Kish and D.A. Schrier, Phys. Rev. C., 41, 1990.

5. A formula for calculating partial cross sections for nuclear reactions of nuclei with $E \geq 200$ MeV/nucleon in hydrogen targets, W.R. Webber, J.C. Kish and D.A. Schrier, Phys. Rev. C, 41, 1990.